EXHIBIT 14

Remedial Investigation Report (Excluding Tables, Figures & Appendices) (November 2016)

PREPARED FOR
W.R. GRACE & CO.-CONN AND
U.S. ENVIRONMENTAL
PROTECTION AGENCY

Remedial Investigation Report
Operable Unit 3 Study Area

Libby Asbestos Superfund Site, Libby, Montana

NOVEMBER 2016

FINAL REPORT - REVISION 1

MWH

BUILDING A BETTER WORLD

FINAL

Remedial Investigation Report

Operable Unit 3 Study Area
Libby Asbestos Superfund Site, Libby, Montana

Revision 1 - November 2016

Prepared for and with Oversight by:

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PROJECT MANAGEMENT

TITLE AND APPROVAL SHEET

Title: Remedial Investigation Report Operable Unit 3 Study Area Libby Asbestos Superfund Site, Libby, Montana – Final Revision 1

Approvals:

This Remedial Investigation Report is approved for implementation without conditions.

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LIST OF ACRONYMS AND ABBREVIATIONS

^oF	degrees Fahrenheit
amsl	above mean sea level
cc^{-1}	per cubic centimeter
cfs	cubic feet per second
cm^2	square centimeter
f/cc	fibers per cubic centimeter
ft.	feet
gpm	gallons per minute
µm	micrometer
µg/L	micrograms per liter
MFL	million fibers per liter
mL	milliliter
mm	millimeter
mg/kg	milligram per kilogram
mg/L	milligram per liter
Ms/cm^2	million structures per square centimeter
Ms/g	million structures per gram
Ms/g-dw	million structures per gram dry weight
s/cc	structures per cubic centimeter
s/mL	structures per milliliter
s/mm^2	structures per square millimeter
s/g	structures per gram
s/g ww	structures per gram wet weight
%	percent
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to
ABS	Activity Based Air Sampling
AOC	Administrative Settlement Agreement and Order on Consent
AHERA	Asbestos Hazard and Emergency Response Act
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	All-Terrain Vehicle
BERA	Baseline Ecological Risk Assessment
BCS	Biological Condition Score
BHI	Billmayer and Hafferman, Inc.
BMI	Benthic Macroinvertebrate

BNSF	Burlington Northern and Santa Fe
BTAG	Biological Technical Advisory Group
CARB	California Air Resources Board
CB&I	CB&I Federal Services, LLC
CDM Smith	CDM Smith Federal Programs Corporation (CDM Smith)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Chain of Custody
COPC	Constituent of Potential Concern
CSF	CDM Smith Close Support Facility
CSS	Contaminant Screening Study
CWA	Clean Water Act
DO	Dissolved Oxygen
DQA	Data Quality Assessment
DSR	Data Summary Report
e.g.	Exempli gratia
etc.	Et cetera
et al	Et alii
EDD	Electronic Data Deliverable
EDS	Energy Dispersive Spectrometry
ELI	Energy Laboratories, Inc.
EMAP	Environmental Monitoring and Assessment Program
EMSL	EMSL Analytical, Inc.
EPH	Extractable Petroleum Hydrocarbon
EPA	U.S. Environmental Protection Agency (or EPA)
ESATR8	Environmental Services Assistance Team Region 8 Laboratory
FEMA	Federal Emergency Management Agency
FBAS	Fluidized Bed Asbestos Segregator
FOH	Federal Occupational Health Service
FS	Feasibility Study
FSDS	Field Sampling Data Sheet
FSRZ	Fire Suppression Restriction Zone
FSSR	Field Sampling Summary Report
FTL	Field Team Lead
Golder	Golder Associates, Inc.
H&S	Health and Safety
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response (40-Hour)
HDR	HDR Engineering, Inc.
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HQS	Habitat Quality Score
HSI	Habitat Suitability Index
i.e.	Id est
ID	Sample identification number
ISO	Internal Organization for Standardization

K	Potassium
KDC	Kootenai Development Company
KDID	Kootenai Development Impoundment Dam
LAA	Libby Amphibole Asbestos
LiDAR	Light Detection and Ranging
LRC	Lower Rainy Creek
Ma	Million Years Before Present
MCL	Maximum Contaminant Level
MDEQ	Montana Department of Environmental Quality
MDNRC	Montana Department of Natural Resources and Conservation
MDSP	Dam Safety Program
MRL	Minimal Risk Level
MT	Montana
MWH	MWH Americas, Inc.
Na	Sodium
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NOAA	National Oceanic & Atmospheric Administration
NPL	Nationals Priorities List
NR	Non-Regulated
NRCS	Natural Resources Conservation Service
NVLAP	National Voluntary Laboratory Accreditation Program
OBTF	Open Burn Test Facility
ORP	Oxidation / Reduction Potential
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
OU3	Operable Unit 3
PAH	Polycyclic Aromatic Hydrocarbon
PCB(s)	Polychlorinated Biphenyls
PCM	Phase Contrast Microscopy
PCME	Phase Contrast Microscopy-Equivalent
PE	Performance Evaluation
PERL	Parametrix Environmental Research Laboratory
PFMA	Potential Failure Mode Analysis
Pioneer	Pioneer Technical Services, Inc.
PLM	Polarized Light Microscopy
PLM-Grav	Polarized Light Microscopy, Gravimetric
PLM-VE	Polarized Light Microscopy Visual Area Estimation
PM	Particulate matter
$PM_{2.5}$	PM less than or equal to 2.5 μm
PPE	Personal Protective Equipment
PPRTV	Provisional Peer Reviewed Toxicity Values for Superfund
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QATS	Quality Assurance Technical Support
RBC	Risked Based Concentration
RCC	Rainy Creek Igneous Complex

RfC	Reference Concentration
RI	Remedial Investigation
RME	Reasonable Maximum Exposure
ROD	Record of Decision
ROM	Record of Modification
RPM	Remedial Program Manager
SAP	Sampling and Analysis Plan
SAED	Selected Area Electron Diffraction
SC	Specific Conductance
SOP	Standard Operating Procedure
SPF	Sample Preparation Facility
SPP	Soil Preparation Plan
SRM	Standard Reference Material
SRC	SRC, Inc.
SVOC	Semi-Volatile Organic Compounds
TDS	Total Dissolved Solid
TEM	Transmission Electron Microscopy
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
UCL	Upper Confidence Limits
URC	Upper Rainy Creek
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USDA	U.S. Department of Agriculture
USDAFSR1	U.S. Department of Agriculture Forest Service Region 1
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USPHS	U.S. Public Health Service
UV	Ultraviolet Light
VOC	Volatile Organic Compounds
VW	Vermiculite Waste
WVB	Whitlock-Vibert box
XRD	X-ray diffraction

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1 INTRODUCTION

This report summarizes the results and conclusions of remedial investigation (RI) activities performed through September 2015 at the Operable Unit 3 (OU3) Study Area within the Libby Asbestos Superfund Site (Libby Site), located near the town of Libby, Montana (MT). These data were used to evaluate possible human and ecological risks posed by the OU3 Study Area, and also will be used to support evaluation of remedial alternatives in a future Feasibility Study (FS). The location of the OU3 Study Area is shown on **Figure 1-1.**

The OU3 Study Area encompasses a former vermiculite mine, historically known as Vermiculite Mountain, and the areas adjoining the mine (shown on **Figure 1-1**). The former vermiculite mine began limited operations in the 1920s and was operated on a larger scale by W.R. Grace (currently known as W.R. Grace & Co.-Conn and referred to herein as Grace) from approximately 1963 to 1990. Vermiculite from the mine contains amphibole-type asbestos, referred to as Libby Amphibole Asbestos (LAA).

Inhalation exposure to asbestos has been found to increase the risk of cancer and non-cancer effects in humans (Agency for Toxic Substances and Disease Registry [ATSDR], 2001a). As a result, the Libby Site, including the OU3 Study Area, is of concern to the U.S. Environmental Protection Agency (EPA) because historical mining, milling, and activities ancillary to mining and milling (e.g., subsequent handling and transport of mined material) caused releases of LAA to the environment. Although the mine has ceased operations, and milling and processing of vermiculite no longer occurs, the EPA was concerned that historic or potential continuing releases of LAA from mine-related materials were a potential source of ongoing exposure and risk to current and future residents, forest workers, trespassers, and possible recreational users within the publicly owned forested areas. Based on these concerns, the EPA listed the Libby Site on the National Priorities List (NPL) in October 2002. **Figure 1-2** depicts the operable units (OUs) within the Libby Site, with the OU3 Study Area highlighted. The operable units are described in **Section 1.3.2**.

Kootenai Development Company (KDC), a subsidiary of Grace, owns the mine and land surrounding the mine (the property boundary within the OU3 Study Area is shown on **Figure 1-1** and is referred to herein as the Former Mine Area). The EPA entered into an Administrative Settlement Agreement and Order on Consent (AOC) with respondents Grace and KDC in 2007 (EPA, 2007a; Docket No.CERCLA-08-2007-0012). Under the terms of the AOC, Grace, the EPA, and KDC jointly performed the RI at the OU3 Study Area.

Numerous Libby Site and OU3 Study Area EPA-approved documents were utilized in the development of this report including, but not limited to: Sampling and Analysis Plan/Quality Assurance Project Plans (SAP/QAPP), Data Summary Reports (DSR), Field Sampling Summary Reports (FSSR), and Risk Assessments. The specific document titles are referenced when applicable throughout the remainder of this document and are listed in **Section 10.0**.

1.1 PURPOSE OF REMEDIAL INVESTIGATION

The purpose of the OU3 Study Area RI activities has been to:

1. characterize the nature and extent of potential impacts within the OU3 Study Area resulting from historical mining, milling, and activities ancillary to mining and milling,
2. describe the fate and transport of these potential impacts,

3. provide information relevant to the assessment of human and ecological risks, and
4. obtain data to support the evaluation of remedial alternatives in the FS.

This RI report presents and interprets the data generated from RI activities that were conducted at the OU3 Study Area between September 2007 and September 2015. **Appendix A** provides a compilation of the pre 2007 data collected within the OU3 Study Area, however, the data will not be utilized in evaluations moving forward in this report because the data collection objectives differed from the data collected post 2007 as part of the OU3 Study Area RI. Refer to **Section 1.3.3** for a discussion on the pre 2007 data sample collection. Investigation-specific SAPs and FSSRs, which describe the implementation of the SAPs, field quality control procedures, and the results of field and laboratory audits, have been submitted for a majority of the RI activities and are referenced in this report. A presentation of sampling investigation details by sampling phase/event is presented **Section 4.0**.

1.2 REPORT ORGANIZATION

This report generally follows the outline suggested in *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final* (EPA, 1988a) and consists of nine sections. Each of the sections is described below.

Section 1.0 **Introduction** – Describes the OU3 Study Area background, including regulatory framework, purpose/objectives of the RI Report, and organization of this document.

Section 2.0 **Physical Characteristics** – Describes the physical characteristics of the OU3 Study Area and surrounding areas, including: physiography, location and access, topography, demography and land use, climatic and meteorological information, geologic conditions, soils, hydrogeology, surface water hydrology, groundwater and surface water geochemistry evaluation, ecological setting, and potential sources of LAA-bearing material and other non-asbestos constituents that may be elevated as a result of historical mining-related activities.

Section 3.0 **Data Collection and Management** – Provides an overview of sampling activities, the OU3 Study Area database, excluded datasets, analytical methods, and Quality Assurance/Quality Control (QA/QC) measures.

Section 4.0 **Summary of Study Area Investigations** – Summarizes the specific studies and resulting data that are being used to characterize the OU3 Study Area and to support risk assessments and the FS.

Section 5.0 **Nature and Extent of Contamination** – Describes the type (nature) and distribution (extent) of contamination within individual media that may be associated with the OU3 Study Area.

Section 6.0 **Contaminant Fate and Transport** – Evaluates the fate/persistence of contaminants in the environment and describes the routes of potential contaminant migration in the affected environmental media, contaminant persistence in the migration pathway, and if evidence of migration is currently observed.

Section 7.0 **Risk Assessment for LAA and Non-Asbestos Constituents** – Summarizes the findings of the Baseline Ecological Risk Assessments *(BERAs*) and the Human Health Risk

Assessments (*HHRAs*), for both LAA and non-asbestos constituents (CDM Smith Federal Programs Corporation [CDM Smith], 2014a; CDM Smith, 2014b; EPA, 2014a; EPA, 2015a).

Section 8.0 Potential Data Gaps - Presents potential data gaps identified during review of the RI data presented in this report. The need to fill any of the potential data gaps will be further evaluated as part of the OU3 Study Area FS.

Section 9.0 Summary and Conclusions – Summarizes the LAA and non-asbestos data from the preceding sections and presents preliminary conclusions based on results of the investigations completed to date and the BERA and the HHRA documents for LAA and non-asbestos constituents.

Section 10.0 References – Lists the reference documents cited in this RI Report.

All tables and figures cited in the text are provided at the end of the report. Appendices are provided electronically.

1.3 OPERABLE UNIT 3 STUDY AREA BACKGROUND

1.3.1 Vermiculite Mining, Milling, and Processing

Numerous hard rock mines have operated in the Libby, Montana area since the 1880s. Prospectors first located vermiculite deposits in the early 1900s on Rainy Creek, northeast of Libby. Edward Alley, a local rancher, was a prospector who explored the old gold mining tunnels and digs in the area (CDM Smith, 2014a). In 1919, Alley purchased the Rainy Creek claims and started the vermiculite mining operation called the Zonolite Company. Alley experimented with the vermiculite and discovered that it had good insulating qualities. Over time, vermiculite became a product used in insulation, feed additives, fertilizer/soil amendments, construction materials, absorbents, and packing materials. Many people used vermiculite products for insulation in their houses and soil additives in their gardens.

Operations at the mine included blast and drag-line mining and milling of ore (CDM Smith, 2014a). Before the construction of an on-site mill, ore was transported by skip and trucked to Libby for processing. Until 1936, the Zonolite Company operated a small-scale drying and screening plant in the town of Libby. In 1936, the first on-site mill for vermiculite ore was constructed by the Universal Insulation Company at the base of Vermiculite Mountain (Boettcher, 1963). Over the next 20 years, (dry) mill capacity and efficiency were increased and then in 1954 wet milling was added and operated concurrently with dry milling in 1954. In 1973, a state-of-the-art new wet mill (floatation method) was constructed. From 1974 until mine closure in 1990, the entire milling operation used wet processes (Grace, 1988). Water for use in the on-site wet mill was obtained directly from Rainy Creek. The Mill Pond served as a collection reservoir, from which water was pumped uphill to the mill. During dry periods, when flow in Rainy Creek was insufficient to supply the needs of the mill, makeup water was pumped almost three miles up Rainy Creek from a pump station on the Kootenai River. Beginning in the 1970s, seepage water and fine tailings from the milling process were collected behind the tailings impoundment dam (Kootenai Development Impoundment Dam [KDID]). The Former Mine Area features, including the former mill area, KDID, and mine-production created ponds, waste rock piles, and tailings piles, are shown on **Figure 1-3**. Historical photographs of the Former Mine Area and mill site are shown on **Figure 1-4**.

Based on available documents, after milling, concentrated vermiculite was transported from the mill site down the northwest facing hill slope along a tramway to a loading area positioned on the south hill slope above Rainy Creek. The material was then transferred from the loading area into haul trucks for off-site delivery. In the 1950s, a storage and loading station was built on the Kootenai River, along with a conveyor belt that crossed the Kootenai River to facilitate distribution by the Great Northern Railway, the predecessor railroad to Burlington Northern and Santa Fe (BNSF) Railway (OU6). After 1970, vermiculite screening was conducted at the storage and loading station, now referred to as the former Screening Plant (OU2). The former Screening Plant, which was located on the east side of the Kootenai River, and the rail loading facility (OU4) on the west side of the Kootenai River, were utilized until 1990.

After the milling and screening process, vermiculite was either trucked to processing facilities in Libby, or loaded onto rail cars for transportation to plants throughout the United States. At the processing plants, the ore was expanded or "exfoliated" by rapid heating, then exported to market by truck or rail. Historic maps show the location of the "Zonolite Company" processing operation at the edge of the Stimson Lumber Mill (OU5), near present day Libby City Hall. In the early 1950s, the Zonolite Company processing plant was taken off-line and demolished and another processing plant, known today as the former Export Plant (OU1), was utilized from the early 1960s to approximately 1992. This processing plant was located near downtown Libby near the intersection of the Kootenai River and Highway 37.

In 1963, Grace purchased the mine and associated processing facilities and operated them until 1990. In 1972, Grace applied for, and received, an operating permit under the Metal Mine Reclamation Act and mined areas were reclaimed as they were mined out. Over the course of Grace's operation in Libby, invoices indicate shipment of nearly 10 billion pounds of vermiculite from Libby to processing centers and other locations (CDM Smith, 2014a).

After operations ceased in 1990, major reclamation began and included demolition of existing facilities, land re-contouring, and re-vegetation of disturbed areas. As of the date of this report, the remaining 125 bonded acres within the mine permit boundary include 65 acres of coarse tailings, 45 acres encompassing a minor landslide that exposed an old landfill of mine-related material, and 15 acres encompassing the previously excavated and mined ore body and some riprap borrow areas (CDM Smith, 2014a).

Vermiculite from the mine contained varying concentrations of LAA. Historical mining, milling, and processing operations, as well as bulk transfer of mining-related materials and tailings to locations in the Kootenai Valley, were found to have released LAA into the environment.

1.3.2 Regulatory History

Asbestos is a hazardous substance as designated by 40 Code of Federal Regulations (CFR) Section 302.4 of the National Oil and Hazardous Substances Pollution Contingency Plan. In November 1999, the EPA responded to requests from the State of Montana and Lincoln County Health Board to investigate the potential exposure to asbestos related to the former mine operations and vermiculite processing. The EPA Response Team inspected the former mine and processing facilities, interviewed local officials and community members, interviewed a pulmonologist in Spokane, Washington, and collected a set of initial samples. The initial investigation revealed the following:

- There were a large number of current and historic cases of asbestos-related diseases in Libby, MT.

- There was a likelihood that significant amounts of asbestos-containing vermiculite still remained in and around Libby, MT.

A more detailed summary of initial Libby Site evaluation can be found in the EPA Action Memorandum dated May 23, 2000, *Request for a Time Critical Removal Action Approval and Exemption from the 12-month, $2-million Statutory Limit at the Libby Asbestos Site- Export Plant and Screening Plant former Processing Areas, Libby, Lincoln County, Montana* (EPA, 2000a).

These findings led the EPA to initiate a larger scale rapid investigation in December 1999 to meet the following goals (CDM Smith, 2014a):

- Obtain information on airborne asbestos levels in Libby in order to judge whether time-critical intervention was needed to protect public health.
- Obtain data on asbestos levels in potential in-town source areas (at the former Export Plant and Screening Plant), and identify the most appropriate analytical methods to screen and quantify asbestos in source materials.

Under Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; also known as Superfund), the EPA has the authority to complete both removal and remedial actions. To date, removals have been conducted using removal action authority to facilitate the timely removal of the most contaminated areas in the Libby Superfund Site. The initial time-critical actions began at the processing areas in May 2000 (EPA, 2000a). As additional areas requiring removal were identified, amendments to the initial EPA Action Memorandum (EPA, 2000a) were approved for extending the 12-month statutory limit and increasing the fund ceiling and are briefly summarized below:

- **July 20, 2001 –** Amendment for continued removal actions at the former Export Plant and Screening Plant, and expanding the scope of removal actions to include Rainy Creek Road, Libby High School, Libby Middle School, Plummer Elementary, and two private properties (EPA, 2001).
- **May 2, 2002 –** Amendment for expanding the scope of removal actions to address residential/commercial properties in OU4 (EPA, 2002a).
- **May 15, 2006 –** Amendment for removal actions at additional properties in OU4 (EPA, 2006a).
- **June 27, 2006 –** Amendment for expanding the scope of removal actions to include Troy, Montana (OU7) (EPA, 2006b).
- **September 24, 2008 –** Amendment for expanding the scope of removal actions to include specific creeks in Libby and Troy, MT (EPA, 2008a).
- **June 17, 2009 –** Amendment for additional residential/commercial removal actions in Libby and Troy, MT (EPA, 2009a).
- **August 13, 2009 –** Amendment to expand the removal actions to include the Cabinet View Country Club Golf Course (EPA, 2009b).
- **March 14, 2012 –** Amendment to request and document approval for changes to removal action and removal protocols described in the original Action Memorandum and previous Amendments, and to outline a new neighborhood clean-up approach (EPA, 2012a).
- **August 28, 2012 –** Amendment to address the removal of LAA-containing vermiculite waste in the Rainy Creek floodplain near the mine (EPA, 2012b).

In October 2002, the Libby Site was listed on the EPA's Superfund NPL and the project was transitioned from the EPA's Removal Program to the Remedial Program. In 2009, the EPA declared a Public Health Emergency in Libby which allowed for federal health care assistance for persons with asbestos-related disease.

To facilitate a multi-phase approach to remediation of the Libby Site, eight separate operable units have been established. In 2016, as part of the Libby Site Record of Decision (ROD), the EPA established formal NPL boundaries for all OUs except OU3 (EPA, 2016). The OUs are described below and shown on **Figure 1-2**.

- **OU1 –** The former Export Plant is defined geographically by the property boundary of the parcel of land that included the former Export Plant and is situated on the south side of the Kootenai River, just north of the downtown area of the City of Libby, Montana. The property is bounded by the Kootenai River on the north, Montana Highway 37 on the east, the BNSF railroad thoroughfare on the south, and State of Montana property on the west.
- **OU2 –** Includes areas impacted by contamination released from the former Screening Plant. These areas include the former Screening Plant, the Flyway property, the Highway 37 right-of-way adjacent to the former Screening Plant and/or Rainy Creek Road, and privately-owned properties.
- **OU3 –** Is defined in the 2007 AOC as the property in and around the Zonolite Mine owned by W.R. Grace or Grace-owned subsidiaries (excluding OU2) and any area (including any structure, soil, air, water, sediment or receptor) impacted by the release and subsequent migration of hazardous substances and/or pollutants or contaminants from such property, including, but not limited to, the mine property, the Kootenai River and sediments therein, Rainy Creek, Rainy Creek Road and areas in which tree bark is contaminated with such hazardous substances and/or pollutants and contaminants.
- **OU4 –** Is defined as residential, commercial, industrial (not associated with former Grace operations), and public properties, including schools and parks in and around the City of Libby, or those that have received material from Grace.
- **OU5 –** Is defined geographically by the parcel of land that included the former Stimson Lumber Company. OU5 is bounded by the high bank of Libby Creek to the east, the BNSF railroad to the north, and properties within OU4 to the south and west. This operable unit is currently occupied by various vacant structures/buildings as well as multiple operating businesses (lumber processing, log storage, excavation contractor, etc.). Within the boundary of OU5 is the Libby Groundwater Superfund Site, which is not associated with the Libby Site.
- **OU6 –** Owned and operated by the BNSF railroad, OU6 is defined geographically by the BNSF property boundaries from the eastern boundary of OU4 to the western boundary of OU7 and extent of contamination associated with the Libby and Troy rail yards.
- **OU7 –** Includes all residential, commercial, and public properties in and around the town of Troy, MT, approximately 20 miles west of downtown Libby.
- **OU8 –** United States and Montana State Highway rights-of-way and secondary state route rights-of-way within the boundaries of OU4 and OU7.

1.3.3 Previous Investigations of the OU3 Study Area

Prior to beginning Phase I of the RI sampling effort in 2007, only limited data existed on the nature of source materials at the Former Mine Area and on the identity and levels of mining, processing, and mined material disposal related to potential releases from the mine to surrounding areas in the OU3 Study Area (EPA, 2007b). A summary of data that were collected prior to the 2007 RI sampling efforts was presented in the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b) and is provided below by media type (only very limited data regarding sampling procedures, test methods, and detection levels were provided in the report, which is reflected in the summary provided below). Detailed information on test methods, sampling location, etc. for the media presented below are contained in the Libby2 Database, which is not maintained by Grace.

Soils and Mine Wastes. As part of site characterization associated with the EPA's initial response activities at the Libby Site, the EPA collected soil samples that were analyzed for asbestos by Polarized Light Microscopy (PLM) using visual area estimation in accordance with the Site-specific PLM method (i.e., standard operating procedure SRC-LIBBY-03, referred to as "PLM-VE") or the National Institute for Occupational Safety and Health [NIOSH] Method 9002. For PLM-VE, results for LAA are reported in terms of mass percent using semi-quantitative "bins" as follows (refer to **Section 3.0** for a complete discussion on PLM-VE analysis):

- Bin A (non-detect; ND) – LAA is not observed
- Bin B1 (trace) – LAA is present, but at levels below the 0.2% reference standard
- Bin B2 (<1%) – LAA is present at levels at or above the 0.2% reference standard, but below the 1% reference standard
- Bin C (≥1%) – LAA is present at levels at or above the 1% reference standard (quantitative estimates of the LAA mass percent are provided)

For NIOSH 9002, results are reported in terms of tremolite/actinolite[1] as either non-detect (ND), less than 1% (<1%), or a percent estimate (when concentrations were estimated at or above 1%). The following data were reported:

- 92 soil samples along Rainy Creek Road (26 samples were non-detect), 47 samples were <1%, 19 samples with detected concentrations ranging from 2% to 8%),
- four samples along a forest service road (all samples were non-detect),
- 61 samples along the right-of-way for Highway 37 (10 samples were non-detect, 37 samples had trace levels, and 14 samples were <1%),
- 15 samples in Carney Creek Logging Area (three samples were non-detect, 11 samples were < 1%, and one sample reported a concentration of 1%), and
- five samples at a U.S. Forest Service (USFS) logging site above the Amphitheater (all samples were <1%).

There were no pre 2007 non-asbestos constituent data for soil and mine wastes. Sample locations and sample data collected prior to 2007 are provided in **Appendix A** (tables and figures from EPA, 2007b).

[1] Tremolite/actinolite are part of the solid solution series that may comprise LAA. See Section 1.5 and Appendix B-1 for discussion of LAA mineral characteristics.

Surface Waters and Sediments. Grace provided the EPA historic information they collected on surface water quality from 1991 through 1994 (refer to **Appendix A** Water Quality Monitoring Data Reports). Review of these data indicates the following general conclusions: surface water is typically pH neutral and total dissolved solids content are normally less than 500 mg/L. Additionally, the EPA collected surface water and sediment samples from Rainy Creek and the tailings impoundment from 2001 through 2003. Fifteen surface water samples[2] were analyzed for LAA by transmission electron microscopy (TEM) using EPA Method 100.2 and three samples detected LAA fibers longer than (>) 10 micrometers (μm); detected concentrations were 7.459 million fibers per liter (MFL) in "Rainy Creek catch basin (Lower reach)", 0.658 MFL in the "stream above the lower tailings pond", and 1.317 MFL from the "main discharge from lower tailings pond". Additionally, two surface water locations, identified only as upper and lower ponds of Rainy Creek, were analyzed for inorganic constituents, total petroleum hydrocarbons, organochlorine pesticides, polychlorinated biphenyls (PCB), and volatile organic compounds (VOCs). Neither of the two samples contained detectable concentrations of metals, total petroleum hydrocarbons, organochlorine pesticides, selected PCB arochlors, or volatile hydrocarbons. Three sediment samples were analyzed for asbestos by PLM in accordance with NIOSH 9002; one sample collected from the upper tailings pond reported tremolite-actinolite concentrations of 2% and the other two were both non-detect. There was no pre 2007 non-asbestos constituent data for sediment. Sample locations and sample data collected prior to 2007 are provided in **Appendix A.**

Groundwater. Groundwater wells had been installed at the mine and historical sampling records refer to various potable water samples that may have been collected from groundwater wells. In addition, a "new well" was drilled in 1986 to a depth of 405 feet (ft.). This well appears to have been a potable water well. One sample was collected shortly after installation, with results reportedly showing no analytes above applicable drinking water standards for the analyzed constituents: arsenic, barium, cadmium, chromium, lead, manganese, mercury, selenium, and silver. Available historic well locations are presented on **Figure A-4.**

Tree Bark. Ward *et al.* (2006) reportedly collected tree bark samples from six locations in and around Libby in November 2004. Three of these locations were in forested locations within the OU3 Study Area. The tree bark samples were ashed in a muffle furnace, suspended in filtered deionized water, filtered, and sonicated before being prepared for TEM analysis. Identification and measurement of fibers was conducted in accordance with counting methods similar to those specified in the Asbestos Hazardous Emergency Response Act of 1986 (AHERA, 1986; EPA, 2007b) which were utilized to standardize the analytical counting within the laboratories. For the purposes of reporting analytical results, it was assumed that the surface area of each sample was 2 square centimeter (cm^2). Tree bark surface loading results for amphibole ranged from 14 million to 260 million fibers per cm^2. Sample locations and sample data collected prior to 2007 are provided in **Appendix A.**

Air. Before 2007, the EPA had collected numerous personal and stationary air monitoring samples for analysis of asbestos as part of clean-up activities within the OU3 Study Area. Personal air monitoring data were collected for all clean-up workers to ensure that exposures were not above Occupational Safety and Health Administration (OSHA) permissible exposure

[2] The surface water sample concentrations were originally reported in the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b) as structures per milliliter (s/mL) in the tables and fibers per milliliter (f/mL) in the text. For this report, these results were converted to million fibers per liter (MFL) for comparability with later RI studies and for consistency with the National Primary Drinking Water Regulation (NPDWR) Maximum Contaminant Level (MCL) for asbestos.

levels and to determine the appropriate level of personal protective equipment (PPE) needed during clean-up activities. A total of 185 personal air samples were collected and analyzed by TEM; results ranged from 0.00195 to 6.66 structures per cubic centimeter (s/cc). Stationary air monitoring samples were also collected for the Libby Site and most samples within the OU3 Study Area were collected along roadways within the Former Mine Area, along Rainy Creek road, and along Highway 37. A total of 351 stationary air samples were collected and analyzed by TEM; results ranged from:

- 0.00110 to 0.00227 s/cc at the Former Mine Area
- 0.000426 to 0.222 s/cc along Rainy Creek road
- ND along Highway 37

Sample locations for these air samples were not provided in the *Phase I Sampling and Analysis Plan for Operable Unit 3 Libby Asbestos Superfund Site* (EPA, 2007b). However, sample data collected prior to 2007 are provided in **Appendix A.**

Biota. No samples of biota from the OU3 Study Area were analyzed for asbestos or other mining-related contaminants before RI sampling efforts began in 2007. However, EPA's Environmental Monitoring and Assessment Program (EMAP) collected aquatic community data at a station on the Kootenai River about one mile downstream of the confluence with Rainy Creek in August of 2002 (EPA, 2014a). These data are provided in **Appendix A**.

Available data collected prior to 2007 are provided in **Appendix A**; however, the data will not be utilized in evaluations moving forward in this report because the data collection objectives differed from the data collected post 2007. The post 2007 data were collected under one of the QAPPs developed as part of the OU3 Study Area RI per the AOC, whereas the pre 2007 data were collected to support emergency response efforts.

1.4 OPERABLE UNIT 3 STUDY AREA BOUNDARY

The OU3 Study Area includes the property in, and adjacent to, the Former Mine Area, and the geographic areas surrounding the mine that may have been impacted by releases and subsequent migration of hazardous substances and/or pollutants or contaminants from the mine. In addition to the Former Mine Area, former mill area, KDID, mine-production created ponds, waste rock piles, and tailings piles, the other geographic areas within the OU3 Study Area include Rainy Creek, Carney Creek, Fleetwood Creek, the Kootenai River, and Rainy Creek Road. The former vermiculite mine is located approximately 6.5 miles east of the town of Libby, Montana. **Figure 1-5** shows land ownership of the OU3 Study Area and surrounding parcels. KDC, a subsidiary of Grace, owns approximately 3,600 acres of land that includes the Former Mine Area and the surrounding area to a distance of approximately 1 mile radially from the center of the Former Mine Area designated on **Figure 1-3.** Refer to **Section 4.6.1** for a discussion on how the center of the Former Mine Area was designated. The mining-disturbed area of the mine property is approximately 1,100 acres. Land surrounding the KDC property within the OU3 Study Area is mainly within the Kootenai National Forest, which is managed by the USFS (approximately 22,000 acres). Approximately 640 acres of land parcels are owned by the State of Montana, 170 acres of land parcels are owned by the US Corp of Engineers, 2,600 acres of land parcels are owned by Plum Creek Timberlands LP for commercial logging. Approximately 690 acres of land parcels are private (primarily residential) properties near the southern border of the OU3 Study Area and are included as part of OU4. The OU3 Study Area encompasses approximately 32,000 acres,

which includes the above acreage values (excluding properties designated as OU4), and the Kootenai River.

Figures 1-1, **1-2**, and **1-3** show the locations of the mine and the current OU3 Study Area boundary, primary geographic features, and Former Mine Area features. The EPA established this preliminary study area boundary for the purpose of planning and developing the scope of the RI. The OU3 boundary for purposes of the FS and remedy implementation is currently under development.

1.5 LIBBY AMPHIBOLE ASBESTOS CHARACTERISTICS

Asbestos is the primary contaminant associated with releases from mining activities in the OU3 Study Area. The vermiculite ore body in the OU3 Study Area contains naturally occurring amphibole asbestos that is comprised of a range of mineral types and morphologies. Historically, the form of asbestos that is present in the vermiculite ore body was classified as tremolite/actinolite (McDonald *et al.,* 1986; Amandus and Wheeler, 1987a and 1987b). More recently, the U.S. Geological Survey (USGS) performed electron probe micro-analysis and X-ray diffraction (XRD) analysis of 30 samples obtained from asbestos veins at the mine (Meeker *et al.,* 2003). Using mineralogical naming rules recommended by Leake *et al.,* 1997, the results indicate that the asbestos at the Libby Asbestos Site includes a number of related amphibole types. The most common forms are winchite and richterite, with lower levels of tremolite, magnesio-riebeckite, edenite, and magnesio- arfvedsonite. Although Meeker *et al.,* 2003 did not report the presence of actinolite, the authors did note that, depending on the valence state of iron and data reduction methods utilized by other analytical laboratories, some minerals may also be classified as actinolite. The mixture of asbestos present in the OU3 Study Area and in the Libby Site are referred to herein as LAA, but **Appendix B-1** provides a more thorough review of the distinguishing characteristics of amphiboles from the vermiculite ore body that was mined by Grace. For consistency with other Libby Site documents, this document does not attempt to distinguish LAA fibers from the mine from other types of asbestos. USGS has defined LAA as structures having an amphibole selected area electron diffraction (SAED) pattern and an elemental composition similar to the range of fiber types observed in ores from the Libby Mine (Meeker *et al.,* 2003), but the term LAA is not limited to those fibers.

Defining characteristics of the LAA that originated from the Vermiculite Mountain ore body are discussed in **Appendix B-1.** This document incorporates comprehensive data relating to amphibole fibers without regard to whether those fibers originated at the Rainy Creek Complex that was mined by Grace. **Appendix B-1** summarizes analytical approaches that have been used to distinguish LAA originating at the mine ore body from other LAA. The reader should be aware that the term LAA may not be consistently used in discussions about the Libby Site, including this document. As shown in **Appendix B-1**, sodium and potassium at certain concentrations were found in all vermiculite ore body samples that were collected from the mine. Samples collected from other locations that were not impacted by the mine did not contain sodium and potassium within these ranges. **Appendix B-2** provides a copy of the OU3 Study Area project database, which includes information on the sodium and potassium presence, as well as the dimensions (length, width) and mineral classifications, of all LAA structures recorded for the OU3 Study Area samples collected from 2007 through 2015 as part of the RI.

CERCLA lists asbestos as a hazardous substance. EPA considers LAA at the Libby Site a hazardous substance under CERCLA. Refer to **Section 2.6.2** for a discussion of the OU3 Study Area geologic conditions and formation of LAA.

2 PHYSICAL CHARACTERISTICS

2.1 INTRODUCTION

This section describes the physical characteristics of the OU3 Study Area and surrounding areas. Summaries are presented for: (1) physiography and topography, (2) location and access, (3) demography and land use, (4) climate and meteorological information, (5) geologic conditions, (6) hydrogeology, (7) surface water hydrology, (8) groundwater and surface water geochemistry evaluation, (9) ecological setting, and (10) potential sources of LAA containing material and other non-asbestos constituents that may be elevated as a result of historical mining activities.

A Light Detection and Ranging (LiDAR) survey of the site was conducted in 2011 and the spatial information collected from that survey has been used in a variety of ways to support various technical analyses for the OU3 Study Area. A second survey was conducted in 2015 and the survey data will be utilized to perform analysis for: identifying areas in which surface mass wasting or accumulation has occurred in the last four years and an interpretation of the mechanisms that are causing possible mass movement (e.g., erosion, slope instability). This analysis will be provided under separate cover.

2.2 PHYSIOGRAPHY AND TOPOGRAPHY

The OU3 Study Area encompasses approximately 32,000 acres, including the Former Mine Area (historically known as Vermiculite Mountain) and areas near the mine that were potentially impacted by releases from mining activities. Vermiculite Mountain, which was the source of the mined vermiculite ore, lies at the extreme southern end of the Purcell Mountains, in the Northern Rocky Mountains physiographic region. The Former Mine Area is located within the KDC property boundary, which area contains approximately 3,600 acres of which approximately 1,100 acres were disturbed by historic mining activities (refer to **Figures 1-2** and **1-5**).

The Former Mine Area is situated approximately 2.5 miles to the northeast of the confluence of the Kootenai River and Rainy Creek. The mine area is generally hilly and dissected by a number of drainages. Elevations in the OU3 Study Area range from a low of 2,080 ft. above mean sea level (amsl) at the mouth of Rainy Creek to a high of 6,040 ft. amsl at Blue Mountain, about 5 miles north-northeast of the Former Mine Area. The highest point on the mine-disturbed area is 4,204 ft. amsl, at the present location of the OU3 Study Area weather station. A topographic map showing the location of the OU3 Study Area weather station, Blue Mountain, Vermiculite Mountain, and an overview of the OU3 Study Area is shown in **Figure 2-1**.

The areas surrounding and including the OU3 Study Area are characterized by distinct mountain ranges and intervening valleys that were formed and altered by the late Pleistocene Cordilleran ice sheet, a continental glacier that moved from Canada to the southwest over the Libby area (Langer, 2010). Many of the drainages in the Former Mine Area do not have the typical U-shaped bottoms from glaciation, but are V-shaped, suggesting the streams in the area are actively down-cutting into the glacial deposits, which have been shown to contain LAA eroded from Vermiculite Mountain during Pleistocene glaciation (Langer, 2010). Rainy Creek, in the vicinity of the Former Mine Area, however, exhibits the classic U-shape caused by glacial retreat.

Numerous perennial and ephemeral streams drain the Former Mine Area and ultimately discharge as tributaries to the Kootenai River. Drainage patterns are generally dendritic to the Kootenai

River, with no obvious structural control. In most places, the drainages are steep and rugged and the streams have very steep gradients. Rainy Creek is the primary drainage channel in the Former Mine Area and flows into the KDID area from the north. Fleetwood Creek is a tributary drainage that flows into Rainy Creek upstream of the KDID from the east and around the coarse tailing pile north of the mine. Carney Creek flows along the south perimeter of the mine area and enters Rainy Creek downstream of the KDID.

In 1972, Grace began construction on the KDID starter dam and associated tailings impoundment in the former channel of Rainy Creek. The purpose of the KDID was to store fine tailings slurry that was produced by the vermiculite wet mill process. The homogeneous embankment dam was raised in several phases between 1973 and 1980 as tailings were continuously deposited. From the Former Mine Area, Rainy Creek flows southwest approximately 2 miles to the Kootenai River, a major tributary to the Columbia River system (refer to **Figure 1-3** for Former Mine Area features).

The area is moderately to thickly vegetated (refer to **Section 2.10.1**), with hill/mountain slopes typically between 20 degrees to 35 degrees, with some areas of steeper and flatter slopes within the Rainy, Fleetwood, and Carney Creek basins. A coarse tailings pile (also referenced as “old mill tailing”), a by-product of the mill processing of vermiculite, is located to the north of Vermiculite Mountain and the former main mining operations. Piles of un-processed overburden and fragmented rock material, referred to as waste rock piles, are located to the south and southwest of the main mining operations. These areas of coarse tailings and waste rock piles are sparsely vegetated or un-vegetated, except in areas where re-vegetation has recently occurred, and are positioned along the hill slopes and drainages around the Former Mine Area perimeter with existing ground surface grades of 10 degrees to 40 degrees (refer to **Figure 1-3).**

The ore body is expressed as an outcrop dome that is rimmed with Precambrian Belt Supergroup meta-sedimentary rocks. The rim is from 400 ft. to 900 ft. above the top of the mine. These geologic features are discussed in greater detail in **Section 2.6**. The dome is drained by Fleetwood Creek around the north perimeter of the mine and by Carney Creek around the south perimeter. These creeks are tributaries to Rainy Creek, a larger stream that heads at an elevation of approximately 5,000 ft. amsl on the slope of Blue Mountain (refer to **Figures 1-3** and **2-1**).

2.3 LOCATION AND ACCESS

The Former Mine Area permitted area occupies portions of Sections 15, 21, 22, 23, 26 and 27 of Township 31 North, Range 30 West, Montana Principal Meridian (refer to **Figure 2-1**). **Figure 2-1** shows portions of the USGS 1:100,000 Vermiculite Mountain, Alexander Mountain, Swede Mountain, Pony Peak, Banfield Mountain, and Ural Creek topographic quadrangle maps. The Former Mine Area can be reached from downtown Libby by traveling along the north bank of the Kootenai River for 5 miles north-east on Highway 37 and taking Rainy Creek Road for 2 miles north, to the Mill Pond. The pavement ends at Mill Pond, at which point there are several forest and mining roads that can be used to access the Former Mine Area.

Highway 37 is open year-round, but Rainy Creek Road is generally inaccessible due to snow from late fall through early spring. A locked gate and warning signage at the bottom of Rainy Creek Road are used to prevent unauthorized access to the Former Mine Area.

Property undisturbed by mining activity within the KDC property can be accessed by gated, locked forest and logging roads with warning signage which intersects Highway 37 (for areas north,

south, and east of the mine) or gated county roads (for areas generally west of the mine). The forest roads within the OU3 Study Area are not currently maintained by the USFS. Many of the logging roads are narrow, steep, and require the use of high-clearance, four-wheel-drive vehicles.

2.4 DEMOGRAPHY AND LAND USE

The area surrounding the OU3 Study Area is sparsely populated and the largest nearby population center is the town of Libby, Montana, which is located approximately 6.5 miles to the south-southwest of the Former Mine Area. Libby has a population of less than 3,000; 12,000 live within a ten-mile radius of the town (U.S. Census, 2010). The 2010 Census counted 2,628 residents in Libby, with the largest group of individuals being between 45 and 54 years old. **Table 2-1** illustrates the age, gender, and racial distributions of the population in Libby.

In the past, Libby's economy was largely supported by natural resources extraction industries, such as logging and mining. Over time, mining operations and log mills have closed and tourism now is playing an increasing role in the local economy of Libby. Of the 2,628 residents: 2,232 residents were above the age of 16 and 1,125 were employed. Of the employed residents, 76 were in the forestry, agriculture, or mining industries; 235 persons were in arts, entertainment, recreation, accommodation, and food services; 333 were in education, health, and social services; and the remainder were in other industries. **Table 2-2** summarizes the employment distribution by the various economic sectors in Libby.

The land surrounding the Former Mine Area is managed for multiple uses by the USFS and by timber companies for logging. Timber harvesting, fire fuels management, and other activities authorized in the Kootenai National Forest Plan are not presently occurring in the OU3 Study Area because of the concern of disturbing potential LAA impacted media. The area is used by the public for camping, hunting and other recreational activities, and firewood gathering. The mining operations in the OU3 Study Area ceased in 1990 and access to mined property is restricted by signs and locked gates, but trespassers may occasionally enter on foot.

2.5 CLIMATIC AND METEOROLOGICAL INFORMATION

In 2007, a weather station was installed and has been collecting data at the top of the Former Mine Area at an elevation of 4,244 ft. amsl (refer to **Figure 2-1** for OU3 weather station location). The wind speed data collected from this station were utilized for producing a wind rose for the OU3 Study Area (refer to **Figure 2-1**). The predominant wind direction measured at the OU3 Study Area weather station is from the southwest blowing towards the northeast, although it is likely that mountain topography influences local wind direction.

For the purposes of this RI report, the USFS Libby 1 NE Ranger Station data for temperature and precipitation were utilized because it is the closest monitoring station to the Former Mine Area having long-term temperature and precipitation data (i.e., 1981 to present). The USFS Libby 1 NE ranger station is approximately 4 miles downstream from where Rainy Creek meets the Kootenai River, at an elevation of 2,100 ft. amsl (refer to **Figure 2-1** for USFS Libby 1 NE Ranger station location). Climate data for the USFS Libby 1 NE Ranger Station for the period of 1981 through 2010 published online by the National Oceanic & Atmospheric Administration (NOAA, 2014) indicates that the average daytime winter temperature is 28.3 degrees Fahrenheit ($^{\circ}$F) and the average daily minimum temperature in winter is 21.6 $^{\circ}$F. In summer, the average daytime temperature at the Libby ranger station is 65.8 $^{\circ}$F, with daytime highs averaging 84.7 $^{\circ}$F. Average annual precipitation for the 1981 through 2010 period was 18.40 inches at the 1NE Libby

Ranger Station. August and September are typically the driest months, and November, December, and January are typically the wettest months of the year when precipitation occurs primarily in the form of snow. **Table 2-3** presents the 1981 through 2010 monthly and annual averages for temperature and precipitation at the 1NE Libby Ranger Station weather monitoring station.

2.6 GEOLOGIC CONDITIONS

In the Former Mine Area, metasedimentary rocks of the Belt Supergroup are exposed at the surface, except in areas covered with late Pleistocene glacial till, Recent alluvium, or where an igneous intrusive body (Rainy Creek Igneous Complex or RCC) is exposed (Weekes, 1981). The formation of vermiculite and asbestiform amphiboles within Vermiculite Mountain is believed to be the result of hydrothermal alteration of augite within the RCC by high-temperature silica-rich solutions. Geologic and geomorphic processes unrelated to mining and milling of vermiculite ore from Vermiculite Mountain have eroded and re-deposited naturally occurring amphibole asbestos in soils throughout the area. The regional and OU3 Study Area geologic conditions are presented in further detail below.

2.6.1 Regional Geology and Soils

The mountains surrounding the Kootenai Valley generally comprise folded, faulted, and metamorphosed blocks of Precambrian sedimentary rocks and minor basaltic intrusions. Primary rock types are meta-sedimentary argillites, quartzites, and marbles (Ferreira *et al.*, 1992). Vermiculite Mountain lies at the extreme south end of the Purcell Mountains which extend over 200 miles northward into British Columbia. The portion of the Purcell Mountains within northwest Montana is characterized by north-northwest trending folds in rocks of the Precambrian Belt Supergroup (Belt Supergroup). A Supergroup is made up of many lithostratigraphic units, also known as groups, which are generally divided into individual formations. Vermiculite Mountain is positioned in a region where Belt Supergroup strata consisting of fine-grained argilite, carbonate, and quartzite meta-sedimentary bedrock are folded in a series of broad northwest trending anticline and syncline structures subjected to Pleistocene faulting and regional uplift (Weekes, 1981; Langer *et al.*, 2010). Regional high-angle normal faults tend to parallel the north-northwest trending folds and often control the narrow linear valleys representing fault-bounded structural troughs (refer to **Figure 2-2** for regional geology and geologic structures). The regional uplift resulted in long-term continued erosion and stream down-cutting, which established the existing drainage systems. Additionally, intermittent active displacements of the regional faults have continued at a few locations in western Montana.

Geologic and geomorphic processes unrelated to mining and milling of vermiculite ore from Vermiculite Mountain have eroded and re-deposited naturally occurring amphibole asbestos in soils within the Kootenai Valley. During the Pleistocene, glacial advances scoured what is now Vermiculite Mountain and deposited sediments in the Rainy Creek delta of a glacial-created lake named Lake Kootenai which no longer exists. The Kootenai Valley was located beneath the glacial Lake Kootenai, which was a result of glacial advances from the most recent Pinedale glacial advance more than 16,000 years ago (Langer *et al.,* 2010). When the glaciers receded, Lake Kootenai gradually drained, resulting in erosion of the Rainy Creek delta and re-deposition of glacial sediments down the entire Kootenai River drainage below the elevation of 2,450 ft. amsl (Locke and Smith 2004; and Smith, 2006). Glacial Lake Kootenai drained around 11,000 years ago (Ehlers and Gibbard, 1996) and the Kootenai River occupies its present channel. The presence of naturally occurring amphibole asbestos in alluvial sediment layers has been

documented at locations throughout the Kootenai Valley (Adams *et al.,* 2010). For example, Adams *et al.,* 2010 collected four samples with measured levels of LAA taken from various locations in the Kootenai Valley: two samples from the clay pit southeast of the town of Libby collected from deep lacustrine deposits, one sample from the sand pit north of town collected from lake bottom sediments, and one sample taken from a field within town was collected from alluvial cobble pebble gravel. The USGS (Adams *et al.,* 2010) also reported the presence of multiple layers of glacial sediments containing naturally occurring amphibole material from Vermiculite Mountain in active gravel quarries near Libby and that some soils from a sample area within the valley contained a range of 0.004% to 0.047% LAA (by mass) (CDM Smith, 2014b).

The sequence of events that occurred as Pleistocene glaciation waned and ice receded to the north included deposition of lacustrine and glacial outwash sediments sourced from multiple locations, including the area of Vermiculite Mountain, as well as locations to the south, southeast, and north of the Kootenai Valley (Langer *et al.,* 2010). Amphibole asbestos eroded by glaciation was deposited as glacial outwash in the vicinity of Rainy Creek and as lacustrine sediments in nearby areas of glacial Lake Kootenai. Additionally, some of this sediment was dispersed more broadly in downstream locations during erosion and re-deposition associated with changing lake levels as the ice receded and temporarily re-advanced. Much of the glacial outwash and lacustrine sediments observed in the Kootenai Valley were derived from locations other than Vermiculite Mountain. For example, sediment sources in the Libby area other than Vermiculite Mountain include Pipe Creek and Quartz Creek north of Libby, as well as sources south and southeast of Libby. In the Troy area, drainages to the south of Troy fed the glacial lakes that eventually coalesced to form glacial Lake Kootenai, and much of the lacustrine sediments and glacial outwash sediments in the Troy area were likely derived from these sources to the south (CDM Smith, 2014b).

Some material containing amphibole asbestos likely was eroded from Vermiculite Mountain during Pleistocene glaciation and was subsequently deposited over a broad area through deposition of glacial outwash and lacustrine sediments. Sediment samples from glacial deposits analyzed by Langer *et al.,* 2010 show that Pleistocene glaciation likely resulted in amphibole asbestos from Vermiculite Mountain being deposited in lacustrine sediments in glacial Lake Kootenai and re-deposited during glacial re-advancements. Two thin, discrete lake bottom (lacustrine sediment) deposits have been determined to contain LAA-bearing sediments but these lake bottom layers are covered in many places with more than 30 meters of other fine-grained sediments that do not contain LAA from Vermiculite Mountain (Langer *et al.,* 2010). The distribution of lacustrine sediment layers that potentially contain LAA from Vermiculite Mountain was described in Langer *et al.,* 2010. Ongoing erosion of the lacustrine sediment exposures, as well as disturbance of sediments by human activity, likely resulted in additional dispersal of glacial deposits that potentially contain amphibole asbestos (CDM Smith, 2014b).

In some locations in the Kootenai Valley, residual soils have formed in lacustrine sediments, glacial till, and loess have been influenced by volcanic ash. The sediments and till are largely derived from the pre-Cambrian sedimentary rocks. Much of the soil within the Libby and Troy communities has been modified by residential construction, industrial operations, and residential activities. These modifications include soil disturbance during construction, road building, railroad operations including grading, gardening, incorporating vermiculite into the soil, and other activities (CDM Smith, 2014b).

The remnant lacustrine sediment terraces that surround Libby generally have a fine-silty textured surficial layer and are underlain by silt loam and clay loam texture sediments (U.S. Department of Agriculture [USDA], 1995). The primary soil type in the town of Libby is National Resource

Conservation Service (NRCS) type 103 – “Andic Dystrochrepts, loamy-skeletal, mixed, frigid” (USDA, 1995). The fine-textured surficial layers have developed directly from loess, or from mixtures of loess and glacial deposited materials, including lacustrine sediments. The loess in the Kootenai Valley has generally been influenced by volcanic ash depositions. The soil has developed in alluvial deposits and has a surficial layer of gravelly silt loam. This soil is underlain by stratified alluvial deposits of sand, silt, and gravel (USDA, 1995).

X-ray diffraction (XRD) analyses by the USGS of shallow, subsurface soil from more than 10 sites in the Libby area show that the soils are composed of major (>20%) quartz, minor (5% to 20%) muscovite (or illite) and albitic feldspar; and trace <5% orthoclase, clinoclore, non-fibrous amphibole (likely magnesio-hornblende), calcite, amorphous material (probably organic), and possible pyrite and hematite. Other minerals are likely present at levels below 0.5% and are generally not detectable by routine XRD analysis. These mineral components represent the average components for the area and likely vary to some extent depending on local conditions. Surficial soil contains the above components with the addition of more organic material (Van Gosen *et al.,* 2002).

The naturally occurring soil movement discussed above, including soil movement during glacial advances and subsequent non-glacial erosion, re-deposited large amounts of material containing amphibole asbestos that were eroded from Vermiculite Mountain and other areas during Pleistocene glaciation and this material was subsequently deposited over a broad area through deposition of glacial outwash and lacustrine sediments. In an effort to characterize the naturally occurring LAA concentrations in soils collected from around the Libby Site, thought to be representative of background conditions, the EPA prepared the *Final Background Soil Summary Report Libby Asbestos Superfund Site, Montana* (CDM Smith, 2014b). This report also summarizes the results of previous background conditions investigations the EPA has conducted at the Libby Site.

One of the sources of human exposure to LAA at the Libby Site is from outdoor soil containing LAA, especially under circumstances when the soil is being actively disturbed. Measurement of LAA levels released to air during a source disturbance activity is referred to as activity-based air sampling (ABS). The EPA has performed extensive ABS studies at the Libby Site, seeking to characterize airborne levels of LAA that occur in association with soil disturbance activities. In some cases, these studies have detected LAA fibers in ABS air samples collected from locations where the soil is not expected to have mine-related contamination (EPA, 2010a). This raises the possibility there is some “non-zero” background level of LAA in the Kootenai Valley soils and parent materials from which the present soils have developed that is not attributable to anthropogenic (due to human activity) releases from vermiculite mining and processing activities (CDM Smith, 2014b). For the purposes of this discussion, the term “background” is used to refer to soils that are not expected to have been affected by anthropogenic releases from vermiculite mining and processing activities.

Based on the summary report, the following conclusions about LAA background levels in soils from the Libby Site were made:

- LAA structures have been consistently detected in background soils within the Kootenai Valley that are not thought to be affected by anthropogenic releases from vermiculite mining and processing activities. While background soil concentrations are variable, in general, the average total LAA concentration in background soil is about 5E+05 structures per gram (s/g), which is estimated to be approximately 0.014% LAA by mass. However, absolute estimates of soil concentrations have

the potential to be biased high due to the use of the rock flour preparation technique (CDM Smith, 2014b).

- The asbestos structures originating from the Vermiculite Mountain ore body contain detectable levels of both sodium and potassium, whereas other potential sources of LAA may not (CDM Smith, 2014b). These detectable levels of sodium and potassium are a signature of the LAA originating from the ore body. These results indicate that a portion of the LAA structures observed at the Libby Site likely do not originate from the Vermiculite Mountain ore body (Meeker *et al.,* 2003; Gunter and Sanchez, 2009). Outside the Kootenai Valley (i.e., Eureka, Helena, Whitefish), LAA structures observed in soil all lack sodium and potassium and are reported as actinolite or tremolite.
- The concentration of LAA in background soils (<0.02% by mass) is well below the detection limit of traditional PLM methods (e.g., PLM-VE), but may be detectable with fluidized bed asbestos segregator (FBAS) preparation (using the rock flour preparation technique) and analysis by TEM (Januch *et al.,* 2013). Analysis of soil following FBAS preparation appears to be a more sensitive metric of LAA detection in soil than either ABS or field visible vermiculite observations; the FBAS preparation method has not yet been validated, but has been externally reviewed.

Taken together, these results support the conclusion there is a non-zero level of LAA in soils within the Kootenai Valley that is not attributable to vermiculite mining and processing activities at the Libby Site (CDM Smith, 2014b). Further, these results support the data reported by other researchers, including Gunter and Sanchez (2009), Adams *et al.,* 2010, and Langer *et al.,* 2010, indicating that low-level detections of amphibole fibers in background soils within the Kootenai Valley originated from normal geologic and geomorphic processes unrelated to mining and milling of vermiculite ore from Vermiculite Mountain.

2.6.2 OU3 Study Area Geologic Conditions

The OU3 Study Area is located in a region of the Belt Supergroup of northwestern Montana that has been intruded by an alkaline-ultramafic (biotite pyroxenite) body. The Belt Supergroup near the Former Mine Area consists of five formations: Libby, Striped Peak, Wallace, Ravalli, and Prichard Formations. The Libby, Wallace, and Prichard Formations are presented on **Figure 2-2** and are included as part of the Belt Supergroup Series on **Figure 2-3**. In the Former Mine Area the Wallace formation of the Belt Supergroup is exposed at the surface, except in areas covered with late Pleistocene glacial till, or where the RCC, which comprises the upper portion of the biotite pyroxenite intrusion, is exposed (Weekes, 1981). The mined vermiculite ore body is part of the RCC and is enclosed on the surface by the middle units of the Wallace formation (Boettcher, 1963). **Table 2-4** provides the generalized stratigraphy of the OU3 Study Area.

Hydrothermal alteration of the biotite pyroxenite intrusion produced the large, high-quality vermiculite ore body. The vermiculite content of the ore varies considerably, ranging from 30% to 84% (EPA, 2007b). Fibrous and asbestiform amphiboles are present in association with the vermiculite ore. Significant portions of the fibrous amphiboles are located along cross-cutting veins and dikes and in the altered pyroxenite wall rock adjacent to them. The alteration zones, dikes, and veins that range in width from a few millimeters (mm) to meters in thickness are found throughout the ore body. Amphibole content in the alteration zones of the ore body is estimated to range between 50% to 75% (EPA, 2007b). Additional alteration minerals include calcite, K-feldspar, vermiculite, talc, titanite, limonite, pyrite, quartz, and albanite. The USGS performed electron probe micro-analysis and XRD analysis of 30 samples obtained from the exposed

asbestos veins to identify compositional changes across the veins (Meeker *et al.,* 2003). Results indicate that a variety of seven amphiboles exist at the Former Mine Area, including winchite, richterite, tremolite, actinolite, and magnesioriebeckite. Results also conclude that amphiboles within the alkaline RCC are sodium and potassium rich. The EPA refers to this mixture of amphibole minerals as LAA (EPA, 2007b).

The RCC is in the form of a dome rimmed with Precambrian Belt Supergroup formation limestone and quartzite. The RCC is roughly circular in plan view, topographically dome-shaped, and slightly more than 2.5 miles in diameter. The RCC is the largest igneous intrusive body in the area and the only ultramafic intrusion (high in iron and magnesium content) in northwest Montana (Boettcher, 1966a). The rim is from 400 to 900 ft. above the top of the mine. The RCC represents a complex succession of intrusions of igneous rocks into the metasedimentary rocks of the Belt Supergroup. The RCC is described as the upper portion of a hydrothermally altered alkalic igneous complex composed primarily of magnetite pyroxenite and biotitite (Boettcher, 1967). The original ultramafic body is an intrusion into the Precambrian Belt Supergroup of northwestern Montana, likely deposited during the early Cretaceous Period (Langer *et al.,* 2010). This intrusion is concentrically zoned with biotitite / biotite pyroxenite in the center and this center is surrounded by a zone of vermiculite pyroxenite, which is the source of the vermiculite mined from the RCC. The vermiculite pyroxenite zone is in turn surrounded by a zone of magnetite pyroxenite. An irregularly shaped body of syenite intrudes into the southwest portion of the pyroxenite pluton. The altered pyroxenite also is associated with numerous syenite dikes that cut the pyroxenites. The syenite intrusion in turn caused alteration of the pyroxenite resulting in the formation of amphiboles. The formation of vermiculite and asbestiform amphiboles in the RCC is believed to be the result of the hydrothermal alteration of augite by high-temperature silica-rich solutions (Pardee *et al.,* 1929; Boettcher, 1967; Van Gosen *et al.,* 2002; Meeker *et al.,* 2003). Generally, the Vermiculite Mountain amphiboles, which are collocated with the vermiculite, occur as either vein-fillings or replacement of the primary pyroxene of the RCC. Fleetwood and Carney creeks have cut down into the less-resistant magnetitie pyroxenite unit, carving arcuate drainage canyons around the north and south flanks of the intrusion. **Figure 2-3** presents the OU3 Study Area geology map.

Four major fault structures and one syncline are mapped and presented on the OU3 Study Area geologic map as shown in **Figure 2-3**. A northwest trending fault and fold structure appears to be truncated by the RCC, and a second normal fault is mapped with a more east-west orientation to the north of the mine area. No evidence of current active faulting at or near the Former Mine Area has been observed based on the geomorphic features.

Numerous studies of the unusual geological characteristics of the RCC have been conducted, among these:

- Boettcher (1963, 1966a, 1966b, 1967) and Weekes (1981) reported on the geology and petrology of the RCC.
- The mineralogy of the asbestiform amphiboles specific to the RCC was the subject of papers by Gunter *et al.,* 2003, Meeker *et al.,* 2003 and Gunter and Sanchez (2006).
- Gunter and Sanchez (2009) reported on *Amphibole forensics: Using the composition of amphiboles to determine their source*.
- Zinner (1982) installed numerous borings at the mine site and produced a master's thesis on the geohydrology of the RCC.

2.6.3 OU3 Study Area Reconnaissance Survey and Test Pit Geologic Investigation

In 2014, test pit investigations were performed in the vicinity of the KDID and field reconnaissance was performed along the primary drainages to Lower Rainy Creek (LRC). The purpose of the test pit investigation was to evaluate subsurface conditions in the vicinity of the KDID. The purpose of the field reconnaissance was to visually inspect and document the distribution of materials in the primary drainages to LRC. In addition, the field reconnaissance identified soil and rock types, and geologic features in order to develop a geologic base map for the area (refer to **Figure 2-3**). Information regarding the test pit investigations and the reconnaissance survey, including all associated field documentation, is provided in the *Test Pit LAA Results and Creek Reconnaissance Report* (MWH, 2016a). Findings from this investigation are summarized below and in **Section 5.0**.

The geologic materials encountered or observed in the investigation consisted of both natural and displaced materials. These materials, which are illustrated on **Figure 2-3**, include the following:

Natural Geologic Materials Observed:

- pyroxenite bedrock
- glacial (e.g., till, moraine, outwash, and lacustrine)
- alluvium (channel, over-bank, or flood plain)
- colluvium
- buried topsoil

Tailings Materials:

- coarse tailings
- fine tailings

Fill Materials:

- fill materials encountered in the valley bottom between the KDID and the Mill Pond
- road fill including materials placed or reworked for the purpose of constructing access roads
- waste rock piles

Materials Observed Along the Rainy Creek and Carney Creek: During the reconnaissance survey and test pit investigation, glacial till deposits were observed along the lower portion of the valley slopes and along Rainy Creek. The main part of the Rainy Creek valley bottom is underlain by recent alluvium and also glacial-fluvial deposits, with some over-bank or flood plain deposits, along low-lying areas, sub-parallel to the margins of the creek. There are also some areas covered by alluvial fan and/or debris flow deposits, as well as fill materials.

The material surrounding Carney Creek and LRC is predominantly composed of similar alluvial and glacial type deposits as those observed in the test pit investigation program. Light to dark, greenish-gray, fine to coarse sand and silty-sand with gravel of varying lithologies and with visible mica flakes were observed in the creek bed at different locations along lower Carney Creek and over the length of LRC. In addition, based on field observations, LRC appears to be down-cutting into underlying glacial material. Naturally occurring LAA within the glacial deposits would be expected to contribute to LAA in surface water along this stretch of Rainy Creek.

Vermiculite materials also were observed in discrete piles, embankment fills at the Mill Pond and East Tub Gulch ponds, general fill materials (particularly downgradient of the KDID), within pipe backfill and road fill, and in overbank and alluvial deposits along the majority of LRC. All of these vermiculite materials (which may be collocated with LAA-bearing materials), in addition to the naturally occurring materials within the basin, would be expected to have the potential to contribute LAA to surface water.

2.6.4 Unconsolidated and Consolidated Deposits

At the Former Mine Area, where Wallace Formation bedrock and the RCC is not exposed at the surface, it is mantled with late Pleistocene glacial drift, which is heavily consolidated, and/or alluvium and colluvium, which are partially consolidated to unconsolidated, of reworked glacial drift and rock fragments or clasts derived from erosion of local bedrock. In the Pleistocene (2.58 million years before present [Ma] to 0.0117 Ma), extensive glacial action widened and deepened the valleys, including the Rainy Creek valley. The Kootenai River was dammed by a glacier and Glacial Lake Kootenai was formed, which reached a surface elevation of approximately 2,450 ft. amsl, and would have extended up the Rainy Creek drainage approximately 1 to 1.5 miles (MWH Americas Inc. [MWH], 2014a). Numerous episodes of glacier advance and retreat resulted in significant accumulations of glacial till, moraines, outwash, terraces, and glacial lacustrine deposits in the Rainy Creek valley. The unconsolidated deposits typically are very thin on side slopes and thickest in drainage bottoms. It is possible that large amounts of material containing amphibole asbestos were eroded from Vermiculite Mountain during Pleistocene glaciation and this material was subsequently deposited over a broad area, including the Former Mine Area, through deposition of glacial outwash and lacustrine sediments (refer to **Section 2.6.1**).

2.6.5 Soils Developed on the RCC Pluton

According to the *Soil Survey of Kootenai National Forest Area, Montana and Idaho* (USFS and Natural Resources Conservation Service [NRCS], 1995), soils on portions of the RCC pluton that have not been disturbed and removed by mining, are classified as Andic Dystric Eutrochepts developed on loess deposited silt and very fine sand, windblown from glacial outwash and mixed with volcanic ash, over micaceous substrates derived from pyroxenite. This soil is typically light colored, with little clay accumulation in the subsoil. Slopes range from 15% to 35%, with a dendritic drainage pattern. The soil forms at elevations ranging from 2,000 ft. amsl to 5,000 ft. amsl.

For timber management, the soil is classified as having a moderate erosion hazard and high relative productivity. The USDA texture is sand, and the Unified Soil Classification System (USCS) classification is poorly graded sand (SP). The soil is non-plastic. For road construction and maintenance, the soil is classified as having no limitations on excavation, but with cutbank raveling and tread erosion limitations, and a severe sediment hazard rating on roads due to a high content of loose silt and sand. The surficial layer of the soil has moderate erosion susceptibility; the lower layer has severe erosion susceptibility.

2.6.6 Soils Developed on Slopes that Surround the RCC Pluton

Soils on most slopes that face inward toward the basin occupied by the RCC pluton are predominantly Andic Cryochepts developed on glaciated mountain slopes and morainal deposits on a substrate of Wallace Formation metasedimentary rocks (USFS and NRCS, 1995). These soils are typically light-colored, with little clay accumulation in the subsoil. Slopes range from 15%

to 35%, with a dendritic drainage pattern. The soil forms at elevations ranging from 3,000 ft. amsl.to 5,400 ft. amsl.

For timber management, the soil is classified as having a moderate sediment hazard and high relative productivity. The USDA texture classification is very gravelly sandy loam, and the USCS classification is silty sand (SM). The soil is non-plastic. For road construction and maintenance, the soil is classified as having no limitations on excavation, but with cut bank sloughing and tread erosion limitations and a moderate sediment hazard rating on roads. The surficial layer and lower layer of the soil have moderate erosion susceptibility.

2.6.7 Soils in Areas Outside the Rainy Creek Basin

Soil types outside the Rainy Creek basin are predominantly Andic Dystrochrepts and Andic Cryochrepts developed on late Pleistocene (Wisconsinan-age) glacial till deposited by the Cordilleran ice sheet (refer to **Section 2.6.1**). Because the majority of the area soils are developed in similar parent material (glacial till consisting primarily of Belt Supergroup Formation erosional products), local soil type is dependent on aspect, slope gradient, precipitation, temperature, and other factors. Detailed and comprehensive information on soils in the region are contained in the *Soil Survey of Kootenai National Forest Area, Montana and Idaho* (USFS and NRCS, 1995).

2.7 HYDROGEOLOGY

A conceptual hydrogeological interpretation was developed for this report based on available piezometer and well information, surface water flow measurements, geology in the Former Mine Area, and available references. This section of the report provides a brief overview of the hydrogeologic conditions in the area.

2.7.1 Groundwater Measurement

Groundwater wells and piezometers have been installed at the site for different purposes, such as for mine water supply or for groundwater or phreatic surface monitoring. A reconnaissance effort was conducted in the fall of 2007 (during the RI Phase I sampling program) to identify groundwater well locations within the OU3 Study Area. Ten wells were identified within the Former Mine Area. Wells A, C, D, E and H were selected for rehabilitation and redeveloped as part of the 2008 RI Phase II efforts. These wells also were sampled as part of the RI Phase II Part B sampling program discussed in **Section 4.0**. Well locations are shown on **Figure 2-4a.**

Information on the ten identified wells from historical well installation logs, well development records, and field reconnaissance of the wells is summarized in **Table 2-5**. Construction records, which appear to coincide with six of the wells, have been identified and information from the records is included in **Table 2-5**, along with depth to water measurements both before and after re-development. Well B was not rehabilitated in 2008 due to an obstruction in the well. During the 2014 KDID investigation program (discussed in **Section 4.9.2)** the obstruction in Well B was identified as a pump located in the 10-inch steel casing. Also during the 2014 KDID investigation program, six of the wells were located in the field and depth to bottom and depth-to-water measurements were obtained for each. These depth-to-water measurements are provided in **Table 2-5**.

Twelve embankment piezometers were installed during the construction of the KDID. The KDID consists of a starter dam with a maximum height of 50 ft. that was later raised between 1973 and

1980 in a series of five phases using the downstream construction method (in which the centerline progresses downstream with additional raises), reaching a maximum structural height of 135 ft. Six of the piezometers (P and P1 through P5) were installed across the dam crest in approximately 1976 at the completion of the Phase 3 raise (Morrison-Maierle, 1981). The piezometers were extended vertically with riser pipes to the current elevation as part of the Phase 4 and Phase 5 raises, and currently the piezometer surface completions are positioned just upstream of the existing embankment crest. Three additional piezometers were installed in the central downstream slope (PM1 through PM3) and three in the left downstream slope (PM4 through PM6) of the KDID. Although construction details are not available, these piezometers are believed to have been installed as a result of the recommendation made in the Harding and Lawson report, *Geotechnical Evaluation W.R. Grace Dam* (Harding Lawson Associates, 1992), which recommended the installation of new piezometers in the KDID to evaluate the phreatic surface. A single piezometer (A8) was also installed at the toe of the dam as part of the investigation program. An additional monitoring standpipe (A-12) was installed above KDID Drains 10 and 11 in 2012 to monitor observed possible artesian conditions above the drains (Billmayer and Hafferman, Inc. [BHI], 2012).

A summary of information from historical records and more recent piezometer surveys is shown in **Table 2-6** and piezometer locations are presented on **Figure 2-4a**. Groundwater measurements from these piezometers have been recorded on a monthly basis since 2008 (BHI, 2010) as part of the Routine Owner's Inspection for the KDID. These measurements were utilized to evaluate vertical and horizontal groundwater gradients and flow characteristics in and near the KDID, and were used to further develop the hydrogeologic model of the Former Mine Area in the *Kootenai Development Impoundment Dam (KDID) Getotechnical and Hydrogeological Investigation Report* (MWH, 2015a).

In 2014, 21 polyvinyl chloride (PVC) standpipe piezometers were installed and substantial geotechnical data were collected at and around the KDID as part of the 2014 KDID investigation program (refer to **Section 4.9.2**). The standpipe piezometers were completed in sonic drill holes, with a maximum of two nested piezometers per drill hole. The piezometers were completed and isolated in each of four lithological units (i.e., embankment fill, alluvium, glacial materials, and bedrock) using bentonite and cement grout seals. Piezometers were installed so that groundwater piezometric surface elevations can be measured independently in each lithological unit without hydraulic connection between units. These data will be utilized to evaluate vertical and horizontal groundwater gradients and flow characteristics in and near the KDID, and will be used to further develop the hydrogeologic model of the Former Mine Area. A summary of the PVC standpipe piezometers is presented in **Table 2-7** and their locations are provided on **Figure 2-4a**. Detailed information on the KDID investigation program, including associated field documentation, is provided in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* (MWH, 2015a).

2.7.2 Groundwater Flow

At the Former Mine Area, several of the geologic units described in **Section 2.6** have been identified as potentially water-bearing (Zinner, 1982). These include the pyroxenite bedrock units, coarser-grained facies of the glacial deposits, and the alluvial and glacial-fluvial deposits. The upper zone of bedrock in the Former Mine Area is generally dominated by vermiculite pyroxenite and is water-bearing (Zinner, 1982). According to Zinner (1982), the upper 100-200 ft. of the vermiculite pyroxenite is as porous and permeable as sand or sandstone aquifer with an estimated permeability of approximately 1.2×10^{-4} centimeters per second (cm/s), or 0.34 ft. per day (ft./day). Groundwater flow regimes in the water-bearing vermiculite pyroxenite bedrock are

complex and likely structurally controlled by relatively impervious syenite dikes, shears, alteration zones, weathering, fracturing, and rock mineralogy. Where the vermiculite pyroxenite is near the surface, which is the typical condition at the Former Mine Area, a significant portion of the precipitation and surface runoff likely infiltrates through the unsaturated zone in these areas and recharges the bedrock aquifer.

The alluvium and glacial materials represent a water-bearing unit along both Rainy and Fleetwood Creeks and form the foundation of the KDID and the tailings impoundment. These deposits have laterally-discontinuous beds, but as a unit, are continuous under the tailing impoundment and are likely hydraulically connected to the creeks and ponded water bodies in the area. In addition to stream base flows, groundwater potentially flows from the surrounding valley slopes through the glacial outwash material and upper fractured bedrock into the alluvial and glacial deposits along the valley bottom.

To support further understanding of groundwater conditions at the Former Mine Area, measurements of groundwater elevations were collected in 2014 and 2015 at the 21 PVC standpipe piezometers located in the vicinity of the KDID as well as from the limited number of wells located throughout the mine site (refer to **Section 2.7.1**). Groundwater measurements from piezometers screened in bedrock in the KDID foundation as well as several wells at the mine site interpreted to be screened in the pyroxenite bedrock (Wells D, E, and F) were used to prepare a bedrock groundwater potentiometric surface map, which is included on **Figure 2-4a.** The potentiometric surface of the bedrock aquifer displayed in **Figure 2-4a** has an approximate flow direction toward the Rainy Creek Valley, with a gradient of approximately 0.3 ft. per foot (ft./ft.) to the northwest. Groundwater elevation measurements that were collected from piezometers that were screened in non-bedrock (refer to **Table 2-7** for piezometer screen information) were utilized to create a shallow groundwater potentiometric surface map, which is included on **Figure 2-4b**. As shown on **Figure 2-4b**, the groundwater potentiometric surface appears to mimic the general topographic contours within the Rainy Creek Valley, with a gradient of approximately 0.3 ft./ft. to the northwest.

Groundwater data from other water-bearing zones were evaluated in the *Kootenai Development Impoundment Dam (KDID) Geotechnical and Hydrogeological Investigation Report* (MWH, 2015a). As discussed in the report, vertical gradients were calculated in the vicinity of the KDID based on differences in groundwater elevations for nested piezometers within individual borings measured on November 4, 2014. Vertical gradients are defined as the ratio of the difference in piezometric head to the difference in elevation of the piezometers. The results show that on November 4, 2014, gradients were generally downward from the alluvium into the glacial soils and from the alluvium across the glacial soils into bedrock. There was one location (BH-07) that showed a slight upward gradient from the bedrock into the glacial soils.

A non-asbestos groundwater and surface water geochemistry evaluation was completed using Piper and Stiff diagrams for the available surface water and groundwater sample data. This evaluation is presented below in **Section 2.9**.

2.7.3 Groundwater Classification

The Water Quality Act is the primary basis for water quality protection in the state of Montana. The Act provides authority for groundwater standards (Administrative Rules of Montana - ARM 17.30.1001 through 17.30.1045). Groundwater is placed in four classification categories (I through IV) based on its specific conductance (SC) value, which is an index of the amount of dissolved solids in the water. Specific conductance values measured during 2015 in on-site

groundwater wells were evaluated (refer to **Section 2.9** for evaluation details) to assess the groundwater classification. The groundwater within the OU3 Study Area is classified as Class I based on an average SC value of 360 micromhos per centimeter (µmhos/cm) measured in groundwater beneath the Former Mine Area. Per ARM 17.30.1006, Class I groundwater have a natural SC less than or equal to 1,000 µmhos/cm at 25ºC. Class I groundwater is suitable for the following beneficial uses with little or no treatment:

- public and private water supplies;
- culinary and food processing purposes;
- irrigation;
- drinking water for livestock and wildlife; and
- commercial and industrial purposes.

Except as provided in ARM 17.30.1005(2), a person may not cause a violation of the following specific water quality standards in Class I groundwater:

- the human health standards for groundwater listed in DEQ-7;
- for concentrations of parameters for which human health standards are not listed in DEQ-7, no increase of a parameter to a level that renders the waters harmful, detrimental, or injurious to the beneficial uses listed for Class I water. The department may use any pertinent credible information to determine these levels; and
- no increase of a parameter that causes a violation of the non-degradation provisions of 75-5-303, MCA.

ARM 17.30.1006 also provides the specific standards for Class II, III, and IV groundwater. These ARM standards are available on the Montana Administrative Rules Services website: http://www.mtrules.org/gateway/Subchapterhome.asp?scn=17%2E30.10.

2.7.4 Seeps

As presented above in **Section 2.7.2**, the upper zone of bedrock in the Former Mine Area is generally dominated by vermiculite pyroxenite and is water-bearing, but highly permeable, similar to the overlying alluvium (Zinner, 1982). Geologic and structural features in the water-bearing vermiculite pyroxenite bedrock (presented in **Section 2.7.2**) result in zones of variable groundwater potentiometric surface elevations. Zones with high elevation groundwater potentiometric surfaces likely contribute to the observed seeps that emerge seasonally in the valley bottom and on the valley slopes (Zinner, 1982).

Numerous diffuse seeps have been observed within the Former Mine Area that flow at different times of the year. Additionally, small seeps were observed issuing from the valley bottom in a location now covered by the KDID (Harding, Miller, Lawson & Associates, 1971). The source of the seep water likely is snowmelt and precipitation that infiltrates the bedrock highlands surrounding the Rainy Creek basin, and flows basin-ward through the permeable zones discussed above. In the Carney Creek drainage, seeps occur in and around the waste rock piles in multiple locations. Mapped seeps are presented on **Figure 2-4a**.